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Fourth Quarterly Report [Study of Biological Mechanisms in Instrumentation Development]

Gentlemen:

This letter report is a resume of work performed by Allied Research Associates during the fourth quarter of NASA Contract NASw-535

Acoustic Transducers

The mammalian ear has been studied from the point of view both as a displacement detector and pressure transducer, with characteristics of operation somewhat more sophisticated than those of its manmade counterparts.

The extreme displacement sensitivity of the auditory mechanism makes this attractive as a possible prototype of a dynamic transducer. For example, the observable deflection value of the basilar membrane and the stapes appear to be of the order of magnitude of Brownian motion. As a pressure sensing device the extreme dynamic range which the ear can accommodate while maintaining relatively high sensitivity in terms of overpressure against base pressure is particularly remarkable. One feature of this which has not been incorporated into pressure transducers currently in use but which may be particularly valuable for situations involving, for example, hard impacts, is the protective mechanism for high over pressures in the malleus and incus articulation. This joint can dislocate with large deflections of the ear drum and rearticulate when the disturbance has subsided. In this mode of operation the malleus and incus act as a mechanical slip clutch, and as such may serve as a model for a mechanical safety device subject to

occasional excessive overloads. This is a bi-directional safety device working for both high overpressure and under pressure, and protects sensitive sensory mechanisms from transmission of dangerously high pressures.

Chemoreceptors

During this period three current theories of olfaction were critically reviewed and evaluated. The first one considers the concept of specific odor receptors wherein a "lock and key" mechanism is responsible for initiating the olfactory nerve impulses. It is quite probable that a volatile complex organic substance must contain molecules of a prescribed three dimensional shape and size which will fit on certain available molecular sites (also possessing definite shapes and dimensions) in the olfactory receptor membrane. Analogies to this "lock and key" concept may be found in various dyeing processes whereby some dye-stuffs of certain molecular dimensions will dye a fiber, but if their chain is lengthened, then they will not do so, although all the necessary osmophoric groups are still present. It is thought that this is a case of the dye-molecule fitting the available sites.

The second theory considers the infrared and Raman spectra of many odorous molecules whereby intramolecular vibrations are thought to cause resonance or interference with the vibrations of the olfactory surface. In other words, a number of different types of receptors would be necessary to account for the very high informational capacity of the olfactory apparatus in vertebrates; each type being "tuned" to a narrow frequency band and generating a nerve impulse when approached by odorous molecules vibrating with the correct matching frequency.

The third theory examined was developed by Davis and Taylor during the 1950's, wherein it was postulated that odorant molecules can simply disrupt the olfactory cell membrane (which probably consists of oriented lipid and protein molecules) thereby permitting an exchange of sodium and potassium ions across it, thus initiating the nerve impulse in the process. Probably all three of the above theories play a role in olfaction.

The separation of numerous odorants into seven primary odors (probably due to specific stereochemical configurations) of ethereal, camphor-

aceous, musky, floral, peppermint, pungent and putrid leads to an engineering concept of a smell warning device for spacecraft and airplanes whereby the pilot, through his olfactory organ, will perceive characteristic odors signifying the occurrence of a possible malfunction in an important operating unit of the system. This would be in conjunction with the usual red light warning system in use today. The extra few seconds of warning time gained could be quite critical.

Associated Neural Phenomena

Neural Processes

In the previous progress reports the significance of various components of electric field in nerve excitation were discussed. Since then effort has been directed into critical examination of the phenomenological theory of nerve conduction proposed by Hodgkin and Huxley.

A bibliographical investigation into the effects of magnetic fields on nerve conduction revealed little of value with respect to fields the order of 100,000 gauss although it is known that such fields to have biological effects on some species. Investigation of this question has been initiated. This work has a logical, and, in fact, inevitable association with the previous work on electric field configurations and the mathematical theory of nerve conduction. One theme running through all of these considerations is the importance of configuration geometry on physical effects.

Chemical Transmission

The phenomenon of chemical transmission of neural impulses appears to be one of several mechanisms in the transmission of the impulse from one nerve to another. Basically, this process consists of a depolarizing (exciting) compound, such as acetycholine in the initiating neuron, resulting in the depolarization phenomena in the receiving neuron.

This phenomenon does not appear to have been made use of in instrumentation concepts, although it appears to be a reasonable approach to several problems in electronic devices.

For example, it is frequently necessary to include a buffer amplifier in the electronic circuit in order to prevent regenerative effects. The coupling in the chemical transmission is effectively unidirectional and intrinsically non regenerative. In the neural process a summing mechanism

appears to occur whereby the degree of depolarization is proportional to the number of initiating "packets" of chemical exciters, so that one can visualize the application of a chemical system to an information storage system such as would be required in a pulse height analyzer. It must also be noted that both exciting and inhibiting chemical actions have been observed in this type of phenomenon, so that the possibility exists of developing a sum and difference mechanism utilizing this principle of chemical neural transmission.

In the actual neural process there is evidence that the frequency of the impulse in a receiving nerve has an approximately linear function with the degree of depolarization. Of course, this is a characteristic which is specifically dependent upon the nerve characteristics. The concept of chemical impulse or inhibition can probably be more readily transferred to an electro-mechanical device.

The Organization of Sensor Signals

Parallel with the rather specific interest in axon conduction there has been continuing work on the association of neurons in what may be considered operation of the nervous system. Included in this are considerations of the information carrying capacity of bundles of nerve fibers and of neuristors. The organization of signals from receptors on the way to and in the brain is of obvious interest. The motivation for this work is to provide a basis for bionics solutions to man-machine interface problems. A special case of the general problem is the possibility of conveying information to the brain by using senses other than the overloaded visual sense.

Literature and Data Gathering and Evaluation

Throughout this program effort has been directed toward updating, expanding and evaluating the body of biological data and literature on sensor mechanisms. Selected bibliographic references are currently being processed for printing as a portion of the overall report on the program.

Program Personnel

The rate of effort of members of the staff who worked on the contract during the period covered by this report is as follows:

	Rate of effort
S. Koslov, Director, Physical Sciences Division	9%
J. Healer, Bioscientist	39%
C. Jamieson, Senior Physicist	38%
H. Homonoff, Staff Chemist	38%
A. Safirstein, Research Assistant	51%
R. Papirno, Senior Engineer	16%

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